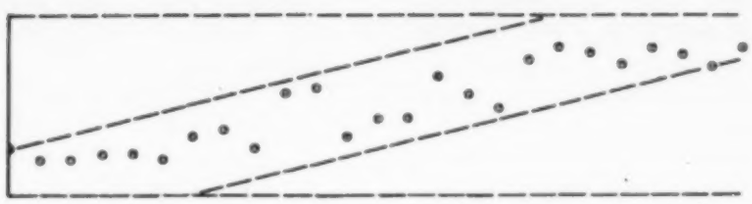
INDUSTRIAL QUALITY CONTROL



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SOCIETY OF QUALITY CONTROL ENGINEERS

IN COOPERATION WITH

THE UNIVERSITY OF BUFFALO

VOL. 1 JULY 1944 NO. 1

PUBLISHED BIMONTHLY
by
The Society of Quality Control Engineers
in cooperation with
The University of Buffalo

Industrial Quality Control is published in January, March, May, July, September and November. All correspondence should be addressed to the Editor at Crosby Hall, University of Buffalo, Buffalo 14, New York.

Industrial Quality Control is sent to all members of the Society of Quality Control Engineers as one of the privileges of membership. Subscriptions are accepted from members of other Quality Control Groups at a nominal price of $2.00 annually. The general subscription rate is $6.00 annually or $1.25 for single issues.

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THE SOCIETY OF QUALITY CONTROL ENGINEERS

A MESSAGE FROM THE PRESIDENT

IT is with considerable pride as President of the Society of Quality Control Engineers that I present this first issue of Industrial Quality Control. Our organization was formed by members of the first War Training Course in Quality Control by Statistical Methods presented by the University of Buffalo. This group following the eight-day concentrated session in September, 1943, felt that continuing exchange of both experiences and technique warranted the formation of this Society.

From this nucleus of 41 representatives of 15 individual industries, our membership has been augmented by graduates of three successive classes in Quality Control, so that we now have an organization of 150 active members.

We propose through the medium of this publication to present to our membership, and the public, items of interest in Quality Control. Prominent among these will be current problems handled by members, technical discussions with accompanying charts and tables, reports of activity and progress in plants of industries using quality control methods, notices of meetings and coming events, and other pertinent notes and comments.

Charles H. Wing

EDITORIAL

MORE than a year ago the War Production Board through its Office of Production Research and Development launched a project to provide training in the use of analytical quality control to key personnel of plants producing war material. In the interim more than a score of intensive short courses in centers producing war materials have been conducted by Dr. Holbrook Working, Dr. Edwin G. Olds and Mr. Paul Peach. Early in this program an intensive course was given in Buffalo, September 11-18.

On November 7 the graduates of this intensive course established the Society of Quality Control Engineers to promote more efficiently the aims expressed in the President's message and to encourage the initiation of training programs for persons whose interest in the subject had developed since the original course.

The Constitution of the Society states that, "The object of this Society is to collect, analyze, and disseminate information concerning Quality Control as applied to industry." This Journal has been launched for the purpose of implementing the quoted article of the Constitution. The membership of the Society has grown to a point such that a printed medium of contact is imperative.

The content of each issue will be selected with the thought in mind that quality control operators in other areas face problems similar to those encountered in the Buffalo area. Accordingly materials appearing will, we hope, have more than local significance. In conformance with that idea the Journal will be made available to members of Quality Control Groups in other centers at a nominal cost.

The quoted article from the Constitution places emphasis on the application of Quality Control. That point of view will be a guiding principle of this publication. Other publications are available for the presentation of statistical and mathematical developments of interest to quality control operators. Likewise the engineering approach is available. But between these two there is an open area of analytical quality control in industrial use. Into this open area Industrial Quality Control is projected as a service to the men and women who make the decisions from day to day in quality control departments.

* * * * *

The editorial work involved in preparing this Journal has been greatly reduced by the able assistance of the authors of articles and by the constant support through managerial advice and proofreading of the members of the Executive Board of the Society of Quality Control Engineers. Cooperation and assistance at the next level should come from the membership of the Society. In addition to the obvious financial support, members can begin thinking now of preparing articles for future issues and supplying new notes and additional bibliography. Articles should relate to the development of quality control procedure in your plants.

SOME AXIOMS OF QUALITY CONTROL

William A. Kerr, Sales Manager
Spencer Lens Company

THE introduction of a system of quality control in any plant requires a major amount of preliminary planning. Much of this planning must be in terms of the particular problems of that plant. It revolves around questions of type of operation, organization plan, kinds of products, individuals involved, and the like. These differences lead to the established fact that each plant's quality control setup will be in the main unlike that of any other plant. Throughout all such systems, however, there runs the common thread of basic method of control by means of statistical analysis, charts, and correlated inspection procedure. Underlying these are certain well established principles which are so much a part of any control system that they have the generality of axioms.

AXIOM I. Wherever like products are turned out in quantity, control chart technique is applicable. Persons unfamiliar with the universality of control chart principles have at times taken the position, "I can see the application to a mass production industry, but my operation is different." It is perfectly true that each operation is different, but the test of applicability is whether like articles are being produced or assembled, either individual units or bulk products. If scrap and rework, customer complaint, and manufacturing difficulty make up any part of the management problem of a plant or individual operation, the control chart procedure will assist in the solution of problems.

AXIOM II. Variability of product is basic in any repetitive operation. Recognition of the pervasiveness of variability is the background of the statistical quality control system. Every type of industrial activity, whether it be machine shop operation, fabrication, assembly, or related productive effort, is characterized by the presence of a cause system which produces a more or less constant variability in the product of the activity. The analysis of this cause system is theoretically possible but not economically desirable, hence for control purposes this phenomenon is labeled the constant cause system of any operation. As such it is segregated from the intermittent or assignable causes of variability by the control chart procedure, so that corrective action can be concentrated on the latter.

AXIOM III. Statistical control should be introduced gradually. There are on record cases in which control chart procedure has been introduced overnight into an entire plant. Perhaps the best known example of this is the work of Colonel Leslie E. Simon at the Picatinny Arsenal at Dover, New Jersey.[1] In spite of the brilliant results obtained by Colonel Simon, the better plan for private industry appears to be the spread of control application as need arises from a small but sound beginning. More commonly management will be skeptical of the results attainable. Accordingly the quality control beginner is faced with the necessity of justifying his program from the start. This is likely to be difficult and time consuming, and in many cases produces disappointments and seemingly insurmountable obstacles to the inauguration of a control system. Patience and wisdom are required, but they eventually will pay personal dividends when the carefully nurtured small beginning expands to a healthy control program.

AXIOM IV. The quality control operator must also be a coordinator. Attempts have been made to inaugurate control systems by the device of acquiring adequate authority from management and then issuing orders to production, inspection, engineering, planning, financial departments, etc. This method is foredoomed to failure. A quality control program must be a joint venture of all of these departments, but experience indicates that the coordination of work and the initiative must be supplied by someone specifically charged with management of the control program.

AXIOM V. Quality must be built into a product; it cannot be introduced through inspection. Plants have sometimes followed the plan of turning out in quantity, product of rather indifferent quality with the expectation that nonacceptable product could be sorted through inspection. Good inspection will improve quality within limits, but this plan brings inspection into constant conflict with production. The goal of better quality is lost in the perpetual struggle to prevent deterioration of quality. Quite apart from the

continued on page 14

1. See An Engineer's Manual of Statistical Methods, Leslie E. Simon, John Wiley and Sons, New York, 1941, pp. 188-203, for a description of methods used.

THE INTRODUCTION OF QUALITY CONTROL AT COLONIAL RADIO CORPORATION

George V. Herrold Chief Inspector
Colonial Radio Corporation

WITHIN the past eight months the use of statistical methods to improve the control of quality of products has been introduced on a large scale basis at Colonial Radio Corporation. The operations of the Corporation lend themselves fairly well to the use of established methods of Quality Control. Nevertheless, several circumstances have arisen which required special treatment. Some of these are presented in this report, others in process of solution form a sizeable part of the continuous problem of managing a control chart system.

In the period since last September about 150 control charts have been inaugurated on more than 100 separate machine parts, subassemblies, assemblies, or related operations. The broad results to date are: (1) a drop of more than 30 per cent in the rejection level of all operations studied; (2) evaluated savings in each of two simple operations at a rate more than sufficient to meet all costs of the Statistical Control Division.

The purpose of this report is to sketch the steps in the development of a system of statistical control and to weave into the discussion examples illustrative of the problems encountered. Perhaps this is the proper point at which to state parenthetically that the author had from the start the sympathetic cooperation of management, and more recently has had the active assistance of management colleagues trained in control chart techniques. In addition, more than 60 members of the supervisory staff of the plant are trained in the use of control chart procedure.

PRELIMINARY PERIOD. The first control charts were set up during November of last year. Prior to that time a period of six weeks was devoted exclusively to thinking about the methods of introducing quality control, and to talking about it with members of the inspection staff and management. Preliminary data were collected and recorded during November on approximately 40 items that appeared to be candidates for treatment by con-

FIGURE I: CONTROL BOARD MAINTAINED IN QUALITY CONTROL OFFICE

trol chart analysis. All of these data related to final assembly and test operations and the charts that were prepared were all of the fraction defective variety.

CONTROL OF ASSEMBLY OPERATIONS. At the beginning of December the first Control Board (reproduced in Figure I) was set up in the Quality Control Office. On this and other boards is posted each morning a record of the previous day's operations. Red + or - signs indicate operations outside 3σ limits; blue + or - signs indicate operations between 2σ and 3σ limits; white solid circles indicate operations within 2σ limits. Thus the quality status of the plant is quickly available to all concerned. The first interest of the Quality Control Division centers, of course, in the red plus signs and to a smaller extent in the red minus signs. These are either on special investigation or, if new, such investigation must be initiated. Those recorded in blue are reviewed carefully to detect any existing trends. Sometimes investigation is started when the level of defectives of an operation is in the blue area persistently. The boards are merely a supplement to the maintenance of an individual chart on each operation.

About the middle of December the interest in the work of the Quality Control Division had spread to inspection supervisors and fraction defective charts began to appear at various points in the inspection area. These were mainly records of final acceptance inspection and test operations on completed equipments. Also appearing at this time was a set of charts relating to output per man-hour of individual testers of completed equipment. This was the period of mushroom growth and several projects were opened up which have since been abandoned, but for the most part the development was sound and spontaneous.

In particular, visual inspection of completed equipments produced a record of the number of defects per unit, but the natural grouping for analysis is one day's production. Hence for charting purposes we use a daily record of the average number of defects per unit computed from each day's production. This is a "c" type chart (based on the Poisson distribution), but the variability is not like the variability of the total number of defects that would be found in a fixed amount of production. The latter type of record would lead to a "c" type chart on which the control limits would be established by the formula,

$$\bar{c} \pm 3\sqrt{\bar{c}}$$

For average defects per unit per day an adjustment of the formula is needed to provide for the fact that the plotted record is really an average "$\bar{c}$" and the average of the daily averages is really "$\bar{c}$". To establish the control limits of this chart we use the formula,

$$\bar{c} \pm 3\sqrt{\frac{\bar{c}}{k}}$$

in which k is the average number of units produced per day during the period used to establish the control limits. The accuracy of projecting these limits for judging the control status of current production depends upon two factors: (1) the continuation of average production at approximately the level of k sets per day; (2) the maintenance of a production rate per day which varies within the range 2k to k/2.

By March 1st most of the control charts of the fraction defective ($\bar{p}$) and number of defects "$\bar{c}$/k" variety were in operation as indicated on the Control Board (Figure I). Routine management of the control system for inspection and test operations is now carried out by the assistant chief inspector and his staff in the Quality Control Division. In the meantime a member of this division has introduced a training program for clerks in the inspection department so that the routine work of recording data will be integrated more efficiently with the procedure in the Quality Control Division. Presumably this training will be repeated periodically to meet a need growing out of upgrading, turnover, and expansion.

CONTROL IN THE MACHINE SHOP. Beginning in April the control chart technique was formally introduced in the machine shop. To be sure, many of the investigations conducted in connection with charts used in assembly had led to machine shop operations and several processes in the machine shop had been altered as a result of such investigations. (This will be apparent in an illustration described subsequently). But the work of collecting data and preparing preliminary control charts for piece parts was done during April.

The average level and characteristic variability were determined in each case from measurement of 16 sub-groups of five pieces each. In some cases the average level proved to be too high or too low and had to be adjusted. In a few cases the variability was excessive with respect to the tolerances. Most of these were brought into control at working levels either by removing causes of variability or by a review of the design re-

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quirements.

About May 1st control charts were introduced on all of the automatic screw machines. These charts are actually cards prepared in the form shown in Figure II. The nominal dimension is considered to be $\bar{\bar{X}}$ and is so placed on the card. The scale records the number of ten-thousandths that individual measured pieces are greater than or less than the nominal. These measurements are recorded by punching the cards as indicated in Figure II. The control limits are simply the nominal $\pm 3\sigma$, where σ is determined through the initial 16 sub-groups of 5 pieces each. (This is σ' in the notation of the American Standards Association pamphlets). Five pieces are inspected directly from the machine at intervals of approximately 30 minutes, and production since the last inspection is kept separate at the machine. If any measurement produces a point outside either control limit, all pieces produced since the last inspection are detailed. Depending upon the results of this inspection and on investigation of the condition of the machine, an immediate decision is made as to whether the machine should continue with minor adjustments or should be shut down. In those cases involving tool wear supervisors study the control charts continuously to determine when the machines should be reset, tools reground, etc.

Simultaneously with the introduction of the control cards in the machine shop, a training course was set up for inspection foremen and supervisors. In this course the instruction was specific on the operation of the cards with enough of the principles of control chart technique interspersed to give a minimum basis for understanding the meaning of the punches on the cards and for taking proper action when punches fall outside the control limits.

More recently control cards have been set up on a few machine operations for which the inspection is simply by Go-Not-Go gauge. This is a patrol inspection at 30 minute intervals for parts which pass through several successive operations. The purpose is to establish assurance that the earlier operations in the sequence are performed correctly and vice versa to assure at later stages of production that earlier work is not lost th ough faulty operation near the end of the sequence.

PURCHASED MATERIAL. Paralleling the activities previously discussed is a separate project in the purchased material inspection departments. Preliminary study showed that a great part of the material was checked 100% and where sampling plans were used, they were mostly inadequate. Improved sampling plans have gradually been introduced as conditions and available staff have warranted. The

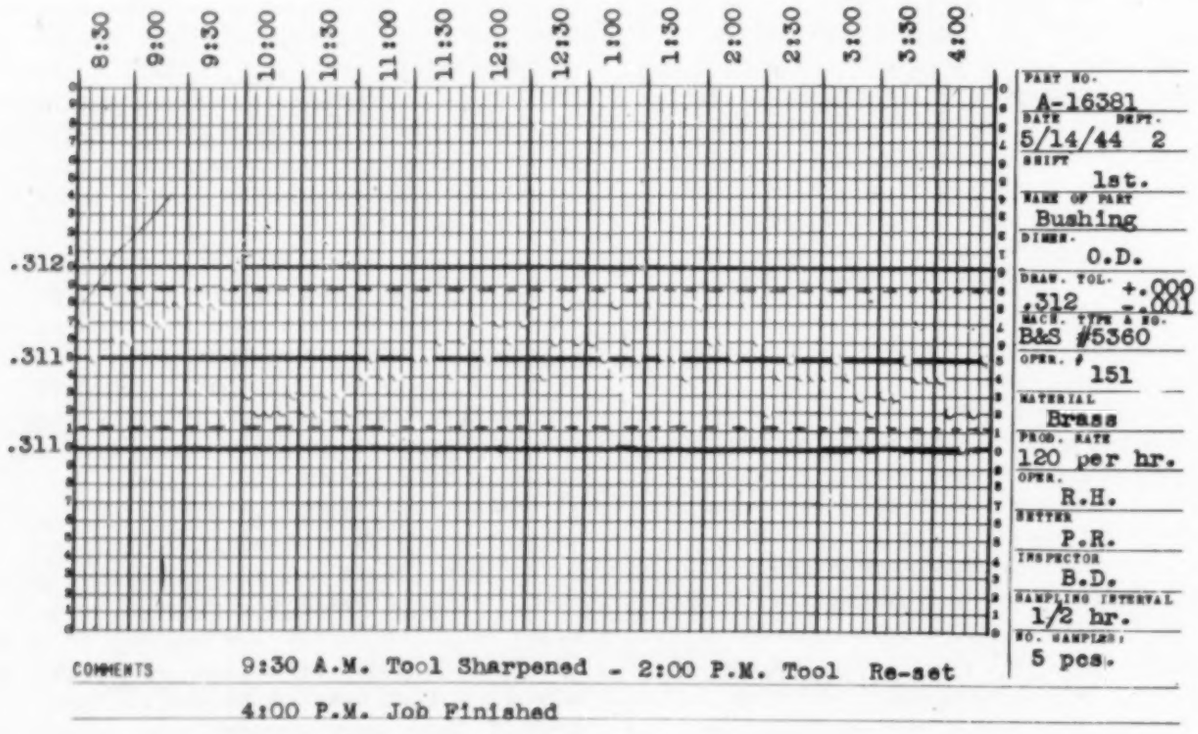

FIGURE II: PUNCH CARD USED BY INSPECTORS AT MACHINES FOR RECORDING MEASUREMENTS OF HALF-HOURLY SAMPLES OF FIVE PIECES

Dodge-Romig plan of Double Sampling with Average Quality Protection has been used with slight modifications in some cases to fit particular circumstances. Experience thus far has shown that the saving in inspection cost for parts which have qualified is in excess of 75 per cent and at the same time there has been a marked improvement in the quality of the material going into production.

RADIO TUBE INSPECTION. In the past, shipments of radio tubes have been accepted without inspection. The argument for this is the fact that the tubes are inspected 100 per cent by the manufacturer and in case a few defectives escape the manufacturer's inspection they are detected quickly as soon as the equipment is tested. While this argument holds in general, occasionally a lot of tubes is received which produces an abnormal amount of trouble in production. This difficulty does not arise frequently enough to justify the use of 100 per cent inspection, but excellent results have been obtained from use of the Dodge-Romig Double Sampling Tables. The detailing or rejection of occasional excessively defective lots has practically eliminated production difficulties and small samples of tubes can be inspected at nominal cost.

Charts are used in tube control for continuous study of the relation between production rejects and true defectives. There is a marked tendency for testers to reject tubes which careful inspection shows to be satisfactory. During five months of operation of these charts the tube reject level has declined 30 per cent. Charts giving the true defect level and its variability have proved invaluable in conferences with field engineers of tube suppliers.

An unusual use of the control chart arose in connection with investigation of a high breakage rate of an extremely fragile but expensive tube. By the simple device of posting charts showing breakage by individual testers and by shifts with upper limits of chance variability on the charts, a healthy competition has developed which results in more careful handling and a consequent marked decrease in breakage.

AN EXAMPLE. At the beginning of this report reference was made to two operations which were improved through application of control chart technique. The procedures followed in eliminating trouble in one of these (known in the plant as the shaft and washer assembly) will be described in some detail as an illustration of the methods used in attacking problems.

Preliminary data were collected on this item during November, but, in spite of a rather high rejection level, no attention was given to the data prior to December 8. On that day the rejection level rose to 68 per cent and an immediate investigation was ordered. The rejection record of this assembly from November to date is shown in Figure IV. Temporary control limits based on $\bar{p}$=15.2% and a high daily rate of production, quickly indicated that strange things began happening on November 25. If the chart had been in operation prior to December 8, it would have given an unmistakable prediction of cumulative trouble.

The investigation immediately showed that most of the washers were too small to fit the shaft properly and that the difficulty lay with the washers. The stamping equipment was adjusted in the machine shop and the stock of washers on hand was discarded. The dimension of the washer is given in the drawing reproduced as Figure III. The total tolerance range of five ten-thousandths is, rather close, but no difficulty was encountered in holding this dimension after a basis for cooperation had been established between the machine shop and assembly inspection.

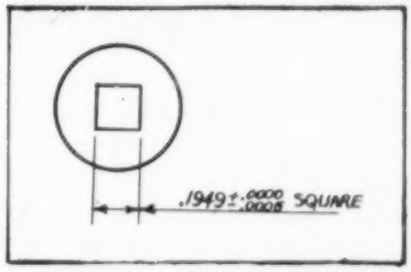

FIGURE III: DIAGRAM OF WASHER

The high level of rejected assemblies during the following six days (December 9-15) was due to the piling up of a large number of assemblies which were known to contain the unsatisfactory washers. From December 16-28 the operation was in relatively satisfactory condition, although the 10 per cent reject level gave no cause for complaisance. In the last three days of December the rejection level climbed sharply, and the investigative effort was redoubled. This time the trouble was discovered in the processing of the washers after the punching operation. The washers must have a certain degree of surface smoothness, but cannot be too smooth; they must also be completely free from burrs. To meet these requirements the following additional operations

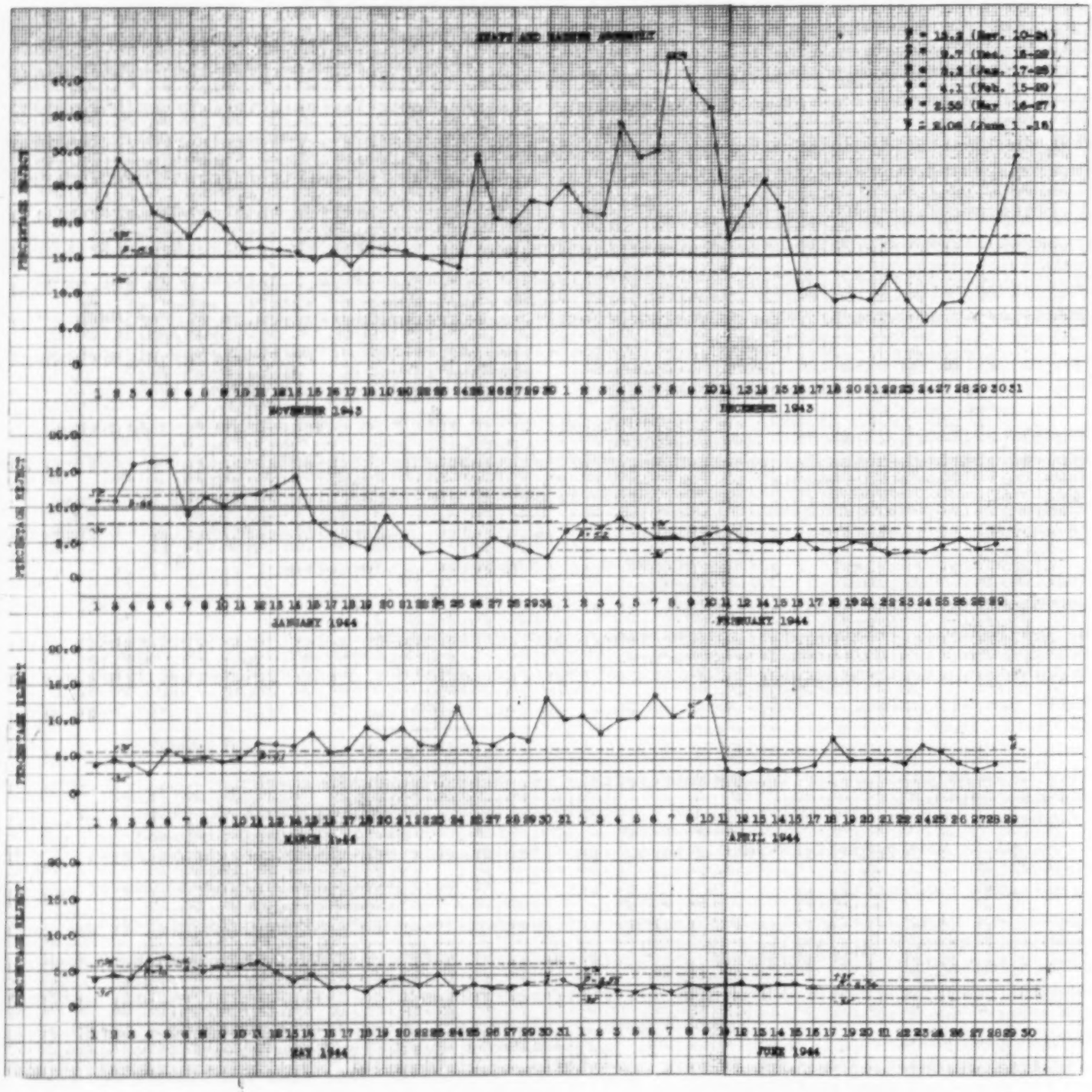

FIGURE IV: FRACTION DEFECTIVE IN ASSEMBLY OF SHAFT AND WASHER, NOVEMBER 1943 TO JUNE 1944.
Three Sigma Limits and Values of $\bar{p}$ Included.

are performed: (1) Rumble for three hours in liquid abrasive; (2) Lap for three minutes in very fine abrasive; (3) Passivate for twenty minutes in a 10% nitric acid solution. The trouble arose in this case because faulty routing had permitted a large number of washers to reach assembly without going through the lapping operation. Correction of this brought the rejection level down at the beginning of January, but on the 4th 5th and 6th roughness again developed in the assemblies.

This time a new operation was added. The washers were tumbled in ground leather for approximately one hour to produce a smooth surface. The effect of this can be seen on January 7, when the rejections dropped to 9 per cent. But roughness developed again and on the 13th and 14th further action was taken. It was found that an excessive amount of oil was being used for protection of the leading edges of the washers. The excess oil seeped in between the washers and had a tendency to bring to the surface small imbedded particles of abrasive. These particles were creating friction which impeded the smooth functioning of the assembly. To correct this, the oil was applied more sparingly.

The effect of these process changes is apparent on the chart. Throughout the second half of January, all of February, and up to March 10, the rejection percentage was much lower than it had been at any time previously and most of the plotted points were inside the nominal control limits expressed on the chart.

Throughout the period covered by this analysis the assembly of the washers on the shaft had been done by selecting washers with holes large enough to fit particular shafts. So many washers were undersize that they had to be laid aside until a shaft near the low tolerance limit was found. As a result of improvements stemming from continuous investigation of this process, the washer dimensions were now being held. Hence on February 15 selective assembly was abandoned in favor of random assembly. The cost of assembly was reduced by more than 50 per cent and the chart shows that the effect, if any, on the rejection percentage was favorable.

Beginning with March 11 trouble arose in reverse. The inspectors were rejecting assemblies because the surface friction between washers was too slight, resulting in slipping of other parts of the assembly. About one month was consumed in locating and eliminating this difficulty. The slipping was caused by the very smooth glazed surface put on the washer by the leather tumbling. The long run solution lay in a reduction of the amount of leather tumbling, but to salvage a large supply of washers in stock all of these were tumbled in sand for three hours to remove the glazed finish.

These glazed-deglazed washers went into assembly on April 11 and the effect on the rejection percentage is obvious. Once more the investigating committee heaved a sigh of relief. It should be noted, however, that the points for the second half of April are somewhat irregular, going out of control twice. This tendency came to a head May 4-11, when inspectors were again rejecting assemblies because of roughness of the washers. Investigation showed that sand particles remaining on the surface of the washers from the temporary tumbling operation were the cause of the roughness.

Beginning May 12 new washers went into assembly. These washers were punched to correct size, rumbled, lapped, passivated, and tumbled in leather for exactly 15 minutes. The effect on the rejection percentage for the second half of May and the first half of June is highly satisfactory. With full confidence that the washer problem has been solved, we are going into the second half of June with the expectation of holding the rejection percentage at or below the level of 2.1 per cent attained June 1-15.

CONCLUSION. Quality Control as an integral part of our operating procedure is in its infancy. The use of charts in inspection and test operations is moderately complete. The greatest part of the installation in the machine shop and in purchased materials inspection is still to be done. Progress should be at an accelerated rate because the introductory work has been done. What remains is concerned mainly with the volume of work that can be carried by the Quality Division and the speed with which adaptations of technique can be devised for different types of operations.

Results thus far cannot be estimated too precisely but it is safe to say that the quality of product has been materially improved, and that notable savings have been accomplished through adjustment of operating and inspection procedures. Perhaps the greatest gain for the future lies in the establishment of an objective basis of cooperation between engineering, manufacturing, inspection and testing, and management.

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NEW DEVELOPMENTS

IN this section of each issue is presented one or more new developments in the field of Quality Control.

Much has been written about the advantages of sampling inspection. Sampling implies that some defectives will go into subsequent operations whatever they may be. A matter which is not widely discussed in the literature, but which must always be kept in mind in devising a sampling plan, is the effect of these defectives in production. Three situations can be catalogued with the corresponding efficient inspection procedure.

100% Inspection

Status of Defectives in Production

(1) No functional test, or cost of replacement at test stage prohibitive.

(2) Functional test certain. For any lot the cost of replacing defectives at the production stage exceeds the cost of detailing the lot.

Sampling Inspection

(3) Functional test certain. For any lot the cost of replacing defectives at the production stage is less than the cost of detailing the lot.

The first situation is obvious enough. It means simply that when replacement of a defective part would be outstandingly difficult or such defective might fail to be detected, then every effort should be made to prevent defectives from going into production. The second and third situations describe most industrial cases. They indicate that the question of whether to introduce sampling involves more than the direct comparison of costs in the inspection department. The determining factor is the relation between the cost of replacing defectives in production and the cost of the inspection necessary to prevent defectives from reaching the production stage.

The diagram on the opposite page gives an objective determination of this relation. Several features of the diagram require explanation. Dollar cost per unit is an indefinite thing due to variability in cost accounting systems. In order to eliminate this factor, time costs are used exclusively. The vertical scale is set up as the ratio of the time to inspect a piece to the time to replace a piece. These times must be obtained from investigation of operations at inspection stations and in production areas. The formation may be available from time study records, but more than likely it will be necessary to go into the shop to obtain the information. In a particular case the inspection time per piece might be 30 seconds, while the time required to remove a defective piece and install a replacement might be 20 minutes. Then the ratio of inspection time per unit to replacement time per unit would be 1 to 40 or as given on the vertical scale of the diagram .025. Inspector time must also be included in the time cost of replacing a defective.

The base scale of the diagram gives the upper limit of the fraction defective of the material that leaves the inspector. This is known as the average outgoing quality limit (A.O.Q.L.). As soon as a sampling plan has been set up for a particular item, the A.O.Q.L. will be known from tables or can be computed.

Direct reasoning will quickly indicate that the greater the fraction defective of the material going into production, the smaller must be the replacement time in relation to inspection time, if sampling inspection is to be efficient. But some simple guide is needed for making a decision with respect to any individual lot. This is provided by the diagonal lines on the diagram which give constant ratios of inspection time for the unsampled remainder of a lot to replacement time for the defectives in the unsampled remainder of a lot. Thus, if the A.O.Q.L. is 2 per cent and the ratio of inspection time per unit to replacement time per unit is 1 to 50 (.02), the ratio per lot is 1 to 1, i.e., it will require the same amount of time to inspect the unsampled remainder of a lot as to replace in production defectives in the unsampled remainder of a lot.

If time in a feeder shop is just as important as time in a machine shop or in an assembly operation, it will be more efficient to use a sampling plan whenever investigation of a particular case produces values on the base scale and vertical scale, respectively, which intersect on or above the 1 to 1 diagonal line. Conversely, if the intersection is below the 1 to 1 line, 100% inspection will be more efficient. In most cases time in the feeder shop would be considered less important than time in the major operations, therefore lines have been drawn for 2 to 1, 3 to 1, 4 to 1, 5 to 1, 10 to 1 and 20 to 1 ratios between time to inspect remainders of lots and time to replace defectives in remainders of lots.

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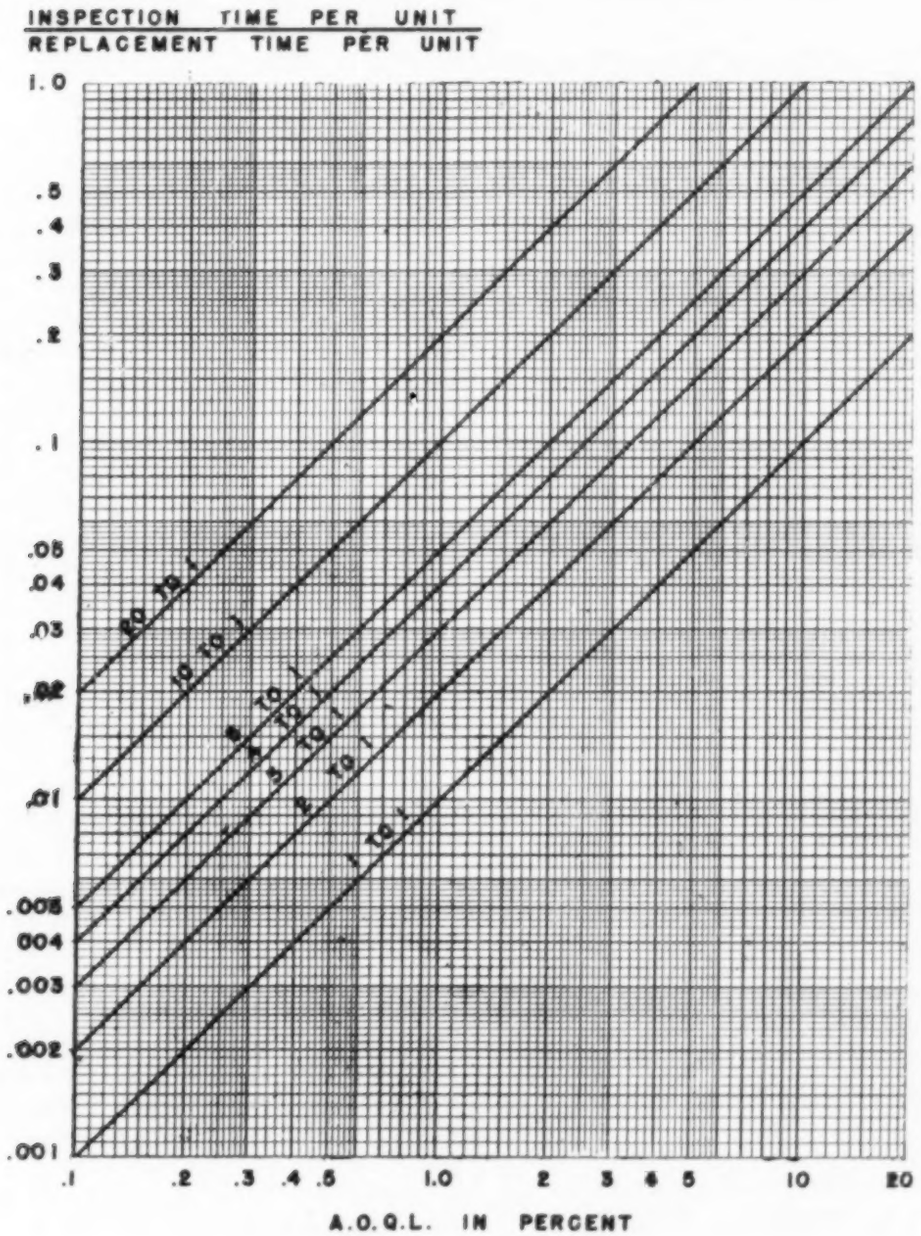
A few examples will show the use of the diagram.

Diagonal line used - 3 to 1 ratio

Vertical Scale	A.O.Q.L. %	Inspection Action
1 to 25 (.04)	3	100%
1 to 200 (.005)	1	100%
1 to 20 (.05)	1	Sample
1 to 5 (.2)	5	Sample

Whenever the quality of product resulting from the use of sampling is better than the A.O.Q.L. indicated in tables or computed, and this will be the case for most lots, the actual circumstances will be somewhat more favorable to sampling than the decision from the diagram. For this reason it is relatively safe to settle borderline cases in favor of the use of sampling.



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3 CONTROL LIMITS FOR FRACTION DEFECTIVE CHARTS

Lot or Sample Size n		Fraction Defective (p)											
		.001	.002	.005	.010	.015	.020	.03	.04	.05	.06	.07	.08
25	U	.020	.029	.047	.070	.088	.104	.132	.158	.181	.202	.223	.243
	L	0	0	0	0	0	0	0	0	0	0	0	0
30	U	.018	.026	.044	.064	.082	.097	.123	.147	.169	.190	.210	.229
	L	0	0	0	0	0	0	0	0	0	0	0	0
40	U	.016	.023	.038	.057	.073	.086	.111	.133	.153	.173	.191	.209
	L	0	0	0	0	0	0	0	0	0	0	0	0
50	U	.014	.021	.035	.052	.067	.079	.102	.123	.142	.161	.178	.195
	L	0	0	0	0	0	0	0	0	0	0	0	0
75	U	.012	.017	.029	.044	.057	.068	.089	.108	.125	.142	.158	.174
	L	0	0	0	0	0	0	0	0	0	0	0	0
100	U	.010	.015	.026	.040	.051	.062	.081	.099	.115	.131	.147	.161
	L	0	0	0	0	0	0	0	0	0	0	0	0
125	U	.009	.014	.024	.037	.048	.058	.076	.093	.108	.124	.138	.153
	L	0	0	0	0	0	0	0	0	0	0	.002	.007
150	U	.009	.013	.022	.034	.045	.054	.072	.088	.103	.118	.132	.146
	L	0	0	0	0	0	0	0	0	0	.002	.008	.014
200	U	.008	.011	.020	.031	.041	.050	.066	.082	.096	.110	.124	.138
	L	0	0	0	0	0	0	0	0	.004	.010	.016	.022
300	U	.006	.010	.017	.027	.036	.044	.060	.074	.088	.101	.114	.127
	L	0	0	0	0	0	0	0	.006	.012	.019	.026	.033
400	U	.006	.009	.016	.025	.033	.041	.056	.069	.083	.096	.108	.121
	L	0	0	0	0	0	0	.004	.011	.017	.024	.032	.039
500	U	.005	.008	.014	.023	.031	.039	.053	.066	.079	.092	.104	.116
	L	0	0	0	0	0	.001	.007	.014	.021	.028	.036	.044
750	U	.004	.007	.013	.021	.028	.035	.049	.061	.074	.086	.098	.110
	L	0	0	0	0	.002	.005	.011	.019	.026	.034	.042	.050
1000	U	.004	.006	.012	.019	.027	.033	.046	.059	.071	.083	.094	.106
	L	0	0	0	.001	.003	.007	.014	.021	.029	.037	.046	.054
2000	U	.003	.005	.010	.017	.023	.029	.041	.053	.065	.076	.087	.098
	L	0	0	0	.003	.007	.011	.019	.027	.035	.044	.053	.062
5000	U	.002	.004	.008	.014	.020	.026	.037	.048	.059	.070	.081	.092
	L	0	0	.002	.006	.010	.014	.023	.032	.041	.050	.059	.068

The limits for fraction defective charts presented in this table are all computed from the formula,

$$p \pm 3\sqrt{\frac{p\,(1-p)}{n}}$$

The purpose is to save the labor of computing in the formula each time a chart is prepared. Thus for fraction defective .02 and sample size 100, the upper 3 σ limit of chance variability is .062 and the corresponding lower limit is 0.

Frequently values of p or n not given in the table will appear in practice. Throughout most of the table the limits corresponding to these odd values will differ in the third decimal place only from values appearing in the table. Therefore little precision will be lost in using the nearest tabulated value. If greater precision is imperative, that can be obtained by simple interpolation. The interpolation can usually be performed by inspection. The details of interpolation for the most complicated case are given in the following example.

Given p = .436, n = 113, to find the control limits exactly.

3 CONTROL LIMITS FOR FRACTION DEFECTIVE CHARTS

Fraction Defective (p)

.09	.10	.12	.14	.16	.18	.20	.25	.30	.35	.40	.45	.50	.60
.262	.280	.315	.348	.380	.411	.440	.510	.575	.636	.694	.748	.800	.894
0	0	0	0	0	0	0	0	.025	.064	.106	.152	.200	.306
.247	.264	.298	.330	.361	.390	.419	.487	.551	.611	.668	.722	.774	.868
0	0	0	0	0	0	0	.013	.049	.089	.132	.178	.226	.332
.226	.242	.274	.305	.334	.362	.390	.455	.517	.576	.632	.686	.737	.832
0	0	0	0	0	0	.010	.045	.083	.124	.168	.214	.263	.368
.211	.227	.258	.287	.316	.343	.370	.434	.494	.552	.608	.661	.712	.808
0	0	0	0	.004	.017	.030	.066	.106	.148	.192	.239	.288	.392
.189	.204	.233	.260	.287	.313	.339	.400	.459	.515	.570	.622	.673	.770
0	0	.007	.020	.033	.047	.061	.100	.141	.185	.230	.278	.327	.430
.176	.190	.217	.244	.270	.295	.320	.380	.437	.493	.547	.599	.650	.747
.004	.010	.023	.036	.050	.065	.080	.120	.163	.207	.253	.301	.350	.453
.167	.180	.207	.233	.258	.283	.307	.366	.423	.478	.531	.583	.634	.731
.013	.020	.033	.047	.062	.077	.093	.134	.177	.222	.269	.317	.366	.469
.160	.173	.200	.225	.250	.274	.298	.356	.412	.467	.520	.572	.622	.720
.020	.027	.040	.055	.070	.086	.102	.144	.188	.233	.280	.328	.378	.480
.151	.164	.189	.214	.238	.261	.285	.342	.397	.451	.504	.556	.606	.704
.029	.036	.051	.066	.082	.099	.115	.158	.203	.249	.296	.344	.394	.496
.140	.152	.176	.200	.223	.247	.269	.325	.379	.433	.485	.536	.587	.685
.040	.048	.064	.080	.097	.113	.131	.175	.221	.267	.315	.364	.413	.515
.133	.145	.169	.192	.215	.238	.260	.315	.369	.422	.473	.525	.575	.673
.047	.055	.071	.088	.105	.122	.140	.185	.231	.278	.327	.375	.425	.527
.128	.140	.164	.187	.209	.232	.254	.308	.361	.414	.466	.517	.567	.666
.052	.060	.076	.093	.111	.128	.146	.192	.239	.286	.334	.383	.433	.534
.121	.133	.156	.178	.200	.222	.244	.297	.350	.402	.454	.504	.555	.654
.059	.067	.084	.102	.120	.138	.156	.203	.250	.298	.346	.396	.445	.546
.117	.128	.151	.173	.195	.216	.238	.291	.343	.395	.446	.497	.547	.646
.063	.072	.089	.107	.125	.144	.162	.209	.257	.305	.354	.403	.453	.554
.109	.120	.142	.163	.185	.206	.227	.279	.331	.382	.433	.483	.534	.633
.071	.080	.098	.117	.135	.154	.173	.221	.269	.318	.367	.417	.466	.567
.102	.113	.134	.155	.176	.196	.217	.268	.319	.370	.421	.471	.521	.621
.078	.087	.106	.125	.144	.164	.183	.232	.281	.330	.379	.429	.479	.579

Upper Limit

n = 100

p	Limit
.40	.547
.45	.599
.05	.052

$.547+(\frac{.036}{.05} \times .052)=.584$

n = 125

p	Limit
.40	.531
.45	.583
.05	.052

$.531+(\frac{.036}{.05} \times .052)=.568$

n	Limit
100	.584
125	.568
25	.016

$U.L.=.584-(\frac{13}{25} \times .016)=.576$

Lower Limit

n = 100

p	Limit
.40	.253
.45	.301
.05	.048

$.253+(\frac{.036}{.05} \times .048)=.287$

n = 125

p	Limit
.40	.269
.45	.317
.05	.048

$.269+(\frac{.036}{.05} \times .048)=.303$

n	Limit
100	.287
125	.303
25	.016

$L.L.=.287+(\frac{13}{25} \times .016)=.295$

INDUSTRIAL QUALITY CONTROL

AXIOMS

continued on page 3

matter of wasting scarce raw materials in wartime, there is a basic fallacy in this scheme. The only way to insure that high quality products will leave the plant is to build quality into the product in the plant, and this means at the machine rather than the inspection bench.

AXIOM VI. Manufacturing processes will usually not be found in a state of control. One of the early steps in the initiation of a control program is the analysis of some existing inspection records. These may be records of a notorious trouble producing operation in which case lack of control is a foregone conclusion. They may be records chosen mainly because of availability, but lack of control is very likely to be found. This is merely a longer way of saying that assignable causes of variation are present in most manufacturing operations, but in the absence of control chart technique they are not recognized. This circumstance is the basis of the universal need for statistical analysis and control.

AXIOM VII. A state of control must be established at a satisfactory level before any product or operation can be approved for routine control chart management. It follows from Axiom VI that most processes will be found out of control initially. The first task of the statistics engineer is to segregate the assignable causes of variability, discover, if possible, their origins, and through cooperative action with representatives of the affected plant functions proceed with corrective steps. This initial attempt to gain control will probably be only partially successful. However, much knowledge will have been gained which will be directly applicable to a second and usually more successful effort to eliminate assignable causes of variability. When such control has been achieved and has been maintained for a sufficient period to eliminate the probability of an accidental occurrence, the time has arrived at which the statistics engineer can assign the operation to a member of his staff for routine management.

It should be noted that there is no suggestion that the control procedure should be removed from the operation when a state of control has been achieved. Experience demonstrates that a standard of quality can be maintained only through continued vigilence. Without the impetus of the control chart, machine operators or assemblers tend to relapse into former habits.

AXIOM VIII. Control chart analysis leads to better product quality with lower inspection cost. The object of the entire quality control procedure is to establish controlled variability of product at a level conforming to the specification and tolerances. In the course of achieving this goal it is most likely that inspection methods will be improved. Particularly, if 100 per cent inspection has previously been employed, the establishment of statistical control of product opens the way for the introduction of sampling inspection. In other cases sampling inspection may have been in use previously, but analysis commonly produces improvements in technique. Under either circumstance the result is better inspection; better quality, and, inasmuch as a controlled process can be maintained with a smaller amount of inspection, less cost.

AXIOM IX. The one indispensable quality of the manager of a quality control program is common sense. Management of a control chart program requires familiarity with plant operations, a background of engineering knowledge, competence in statistical technique, and executive capacity. These things are necessary qualifications but they are not sufficient to guarantee success of a control program. No matter how carefully one is schooled in standard practice, or how carefully each control step is planned, the situations which arise in a plant from day to day are sure to contain unforeseen elements of difficulty. The natural tendency is to attempt to catalog each new situation according to the book. This is good practice and seldom fails to produce some results. However, one must be prepared to find that established procedure will very often not give the answer. At this stage the quality manager must rely on his ability to bring to the new situation a fund of common sense. Common sense or horse sense is essentially the ability to evaluate the elements of a situation correctly, place each one in proper perspective, and make the accumulated information add up to a solution of a problem.

TRADE MARK

The symbol on page 1 is a representation of a control chart with diagonal limit lines drawn within conventional limits. The drawing is intended to suggest measurements of a piece part involving tool wear toward the plus tolerance.

CURRENT PUBLICATIONS AND BIBLIOGRAPHY

A page of each issue of the Journal is devoted to brief reviews of articles on Statistical Quality Control appearing in current publications. Earlier issues of the Journal contain bibliographies of materials published in former years. The purpose is to provide readers with a permanent reference list. In compiling this historical list omissions are inevitable. Assistance from readers by supplying missing references will be appreciated.

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NOTES AND ANNOUNCEMENTS

NATIONAL DEVELOPMENTS IN QUALITY CONTROL

Holbrook Working

DEVELOPMENTS in quality control in the Buffalo area are perhaps not a "representative sample" for the country at large, but they are indicative of what has been happening in numerous areas.

The Buffalo course in September, 1943, was only the eighth such course given - the fourth outside of California. The twenty-first such course was completed on June 29, 1944, at the Georgia Institute of Technology. Nearly 1000 people have now attended such courses for the full period and 1000 more have attended the one-day programs for executives arranged in connection with the courses.

Princeton University plans to offer its second intensive quality control course in early September. Numerous other courses are being planned for the next few months, but dates are not yet available.

Professor Brumbaugh holds the national record for number of students taught in part-time quality control courses during the last nine months. About as many students have taken part-time quality control courses in Los Angeles as in Buffalo, but they have been divided among several instructors.

In February, Los Angeles had its third intensive quality control course, with an attendance of 90 for the full course. The eight-day course given at Pittsburgh last November had a registration of 101.

A series of three-day courses in Statistical Quality Control, under the direction of Mr. G. D. Edwards of the Bell Telephone Laboratories, is being given by the Army Service Forces in Army personnel.

These reports on courses are merely highlights of the more easily visible side of developments in quality control. The more significant story of results accomplished in savings of man-power and of materials and in increase of production has not been recorded in detail. It can never be fully recorded because the contribution of statistics to quality control is often intangible. Many improvements in production and inspection techniques have been made without use of statistical devices which nevertheless owe much to statistics because knowledge of statistical principles supplied a sound and realistic approach to the problem that had been lacking before.

QUALITY CONTROL TRAINING AT SYLVANIA

Walter A. Weiss

THE first training course for quality control personnel at Sylvania Electric Products Corporation was set up by Pennsylvania State College through the Engineering, Science and Management War Training program of the United States Office of Education. In regular meetings between March 28 and June 6 much the same content was presented that is given in the intensive courses of the War Production Board with specific applications added.

Sponsors of this course had the foresight to set aside two six-hour general sessions to be conducted by prominent men in the field of Industrial Quality Control. In accordance with these plans, Mr. Andrew I. Peterson was invited to speak to the Sylvania group on June 12. Mr. Peterson, formerly professor of Engineering Economics of the New York University and now director of Manufacturing Research for the Radio Corporation of America, gave a presentation involving the practical aspects and application of the quality control techniques to industrial problems.

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INDUSTRIAL QUALITY CONTROL

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